Defence Seminar

Seminar Title	: Experimental Investigation of Flow Dynamics and Bed Morphology in a Vegetated Channel
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Venue	: Civil Engineering Seminar Room
Date and Time	: 12 Sep 2025 (4.00 PM)

Abstract :

Vegetation in open channel flows plays a crucial role in altering hydrodynamic behaviour by obstructing flow paths, modifying velocity profiles, and influencing turbulence, which in turn impacts sediment transport. Understanding these interactions is vital for sustainable river management, ecological restoration, and hydraulic infrastructure design. Despite growing interest, the combined effects of vegetation height, submergence, density, and bed conditions on three-dimensional turbulence and sediment transport in narrow channels remain poorly understood.

This thesis presents a comprehensive experimental and numerical investigation of three-dimensional (3D) hydrodynamics and bed morphology in narrow vegetated open channels. Experiments were performed with both rigid artificial vegetation under fixed-bed conditions and natural Vetiver grass in mobile-bed channels. Flow velocity and turbulence characteristics were measured using a down-looking Acoustic Doppler Velocimeter, while bed morphology was monitored using a laser profiler. Ripple-type bedforms developed dynamically under mobile-bed conditions, shaped by local turbulence and sediment transport. Turbulent kinetic energy (TKE) and Reynolds shear stress (RSS) peaked near the bed and channel banks. Numerical simulations using the Realisable k-&epsilon turbulence model in ANSYS Fluent showed good agreement with experimental results, confirming the model&rsquos applicability to narrow-channel flows.. Experiments with emergent rigid vegetation in staggered arrays revealed that vegetation reduced velocity and turbulence within vegetated zones but intensified turbulence and momentum exchange in wake regions. Skewness analysis showed intermittency in turbulent structures, particularly behind vegetation stems. Three-dimensional turbulence properties such as TKE, RSS, and anisotropy varied significantly in both streamwise and transverse directions, with anisotropy invariant maps indicating axisymmetric contraction in vegetated zones and expansion in non-vegetated areas. Complementary numerical simulations successfully reproduced these turbulent characteristics, validated using statistical measures including the coefficient of determination and Nash&ndashSutcliffe efficiency.

The study further examined partially vegetated mobile beds under diverse vegetation configurations: natural emergent vegetation, double-layered submerged vegetation with submergence ratios of 61.53% and 30.77%, and heterogeneous vegetation comprising emergent, just-submerged, and fully submerged stems. Across all configurations, vegetation diverted momentum toward the non-vegetated side, enhancing turbulence and shear stress at the vegetated&ndashnon-vegetated interface. This led to intensified scouring in high-energy, non-vegetated regions and sediment deposition in vegetated zones due to flow deceleration and reduced turbulence. Quantitatively, streamwise velocity in vegetated zones decreased by 50&ndash70% for emergent, 20&ndash40% for heterogeneous, and 15&ndash40% for double-layered submerged vegetation compared to non-vegetated zones. Secondary flow structures such as helical motions and enhanced transverse-vertical RSS further shaped erosion&ndashdeposition patterns. Notably, double-layered submerged vegetation minimized erosion in non-vegetated regions, highlighting its potential for bed stabilization. Overall, this research provides new insights into 3D turbulence, momentum exchange, and sediment dynamics in narrow vegetated channels. It demonstrates how vegetation geometry, submergence, and spatial arrangement govern flow redistribution, energy dissipation, and morphological evolution. The findings enhance predictive modelling of vegetated flows and offer practical guidance for ecohydraulic design, erosion control, and river restoration in vegetated waterways.